# METHOD FOR OPTIMIZING FORWARD LINK DATA TRANSMISSION RATES IN SPREAD-SPECTRUM COMMUNICATIONS SYSTEMS

## FIELD OF THE INVENTION

The present invention relates generally to communications systems and, in particular, to data transmission within a spread-spectrum communications system.

## BACKGROUND OF THE INVENTION

Communications systems are well known and consist of many types including land mobile radio, cellular radiotelephone, personal communications systems, and other communications system types. Within a communications system, transmissions are conducted between a transmitting device and a receiving device over a communication resource, commonly referred to as a communication channel.

One type of communications system known in the art is a spread-spectrum system. In spread-spectrum systems, all communication signals are transmitted simultaneously in the same transmission bandwidth. This modulation technique spreads the frequency spectrum or information bandwidth of each communication signal using a spreading code. Several different spreading codes are used in spread-spectrum systems including, but are not limited to, pseudo noise (PN) codes and Walsh codes. The codes used for spreading have low cross-correlation values and are unique to each simultaneous communication signal. Spreading codes can be used to separate communication signals from one another in a spread-spectrum communications system. Therefore, spreading codes can effectively limit the number of communication signals that can be simultaneously transmitted via the overall transmission bandwidth. One of the main parameters in determining the spreading code for a given communication signal is the processing gain, which is the ratio of the transmission bandwidth to the information bandwidth. When the processing gain is high, the spreading code does not have to separate communication signals as far apart and more communication signals can be simultaneously transmitted. This correlation between processing gain and spreading codes demonstrates how processing gain can also impact the number of communication signals simultaneously transmitted in a system. Since it is advantageous to keep the processing

gain as high as possible, it is equally advantageous to minimize the information bandwidth of individual communication signals, the information bandwidth being inversely proportional to the processing gain.

Spread-spectrum systems include wireless cellular networks that communicate messages to and from mobile devices through a wireless cellular infrastructure. Several types of wireless cellular networks are known in the art and are generally grouped in terms of first generation (1G), second generation (2G) and third generation (3G) technology.

1G wireless cellular networks are based on analog technology. The most widely deployed 1G wireless cellular networks are the advanced mobile phone system (AMPS), Nordic mobile telephone (NMT), and total access communications system (TACS). 2G wireless cellular networks are based on digital technology. 2G wireless cellular networks include IS-95 or cdmaOne, IS-136 or digital AMPS (DAMPS), global system for mobile (GSM), and personal digital cellular (PDC) systems. IS-95 utilizes code division multiple access (CDMA) as its air interface communication protocol. Alternatively, IS-136, GSM, and PDC utilize time-division multiple access (TDMA). 1G and 2G wireless cellular networks currently provide voice services and low-rate data services.

3G is the next generation of wireless cellular technology with its primary focus on seamlessly evolving 2G systems to provide high-speed data services to support various data and multimedia applications, such as web page browsing. To preserve the existing wireless infrastructure, it is preferable for 3G systems to be compatible with existing voice and low-rate data capabilities of 1G and 2G systems. International mobile telecommunications in the year 2000 (IMT-2000) is the 3G specification under development by the International Telecommunications Union (ITU) that will provide standardized requirements for enhanced voice and data services over next generation wireless networks. Proposed 3G wireless cellular networks include cdma2000 and wideband CDMA (WCDMA). Universal mobile telecommunications system (UMTS) is often used synonymously with IMT-2000 and is also frequently used when referring specifically to WCDMA.

The generalized architectural framework of a wireless cellular network is based on the geographic placement of a plurality of base transceiver stations (BTSs), each BTS creating a geographic coverage area known as a cell. A BTS communicates with wireless mobile devices within its cell and such communications are maintained by the wireless cellular network as the wireless mobile devices move geographically from cell to cell. In addition to multiple BTSs, the wireless infrastructure of a wireless cellular network includes at least one base station controller (BSC), at least one selector distributor unit (SDU), and at least one mobile switching center (MSC). Within a wireless cellular network, a forward message refers to a message transmitted by cellular infrastructure equipment for reception by a wireless mobile device. A reverse message refers to a message generated by a wireless mobile device, such as a mobile cellular telephone. The typical wireless cellular communications system communicates with other communications systems, such as a public switched telephone network (PSTN), via the MSC. External interfaces, such as a PSTN interface, provide the wireless cellular network with access to individual computers and distributed computer networks, including local area networks (LANs), wide area networks (WANs), intranets, internets, the Internet, and any other distributed processing and/or storage networks. Within the wireless infrastructure, the MSC communicates with one or more BSCs. A BSC communicates with multiple BTSs. BTSs communicate, over an air interface via a radio frequency (RF) channel, with wireless mobile devices operating within their respective coverage areas through forward and reverse links. An SDU is coupled to the MSC, one or more BSCs, and multiple BTSs. The SDU performs forward link air interface frame distribution to the BTSs.

In a spread-spectrum system that provides wireless access to individual computers and distributed computer networks, it is possible that a given data transmission will be limited in forward link throughput by the throughput of the computer equipment infrastructure, rather than by the wireless link speed. In other words, the bottleneck link speed and information bandwidth of the data transmission is limited by the computer equipment infrastructure. Under such circumstances, transmission bandwidth resources in the spread-spectrum communications system are wasted if a link speed higher than the bottleneck link speed is assigned to the forward link by the wireless infrastructure. In

other words, the wireless link speed should not be much faster than the bottleneck link speed established by certain components of the computer equipment infrastructure.

Consequently, a need exists for an apparatus and method which optimizes the data rate for forward link data transmissions in a spread-spectrum communications system in a manner which maximizes usage of the transmission bandwidth while also maintaining a sufficient quality of service (QoS) to the wireless mobile device.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a typical pathway for an end-to-end data transmission from a sending device to a wireless mobile receiving device in accordance with the preferred embodiment of the present invention.

FIG. 2 is a block diagram of pertinent elements of an SDU in the context of a data transmission from a computer equipment infrastructure to a wireless mobile receiving device in accordance with the preferred embodiment of the present invention.

FIG. 3 is a flow chart illustrating the data rate optimization algorithm of the preferred embodiment of the present invention.

FIG. 4 is a flow chart illustrating an alternate embodiment of the data rate optimization algorithm of the present invention that considers the data rate of the input data transmission.

FIG. 5 is a flow chart illustrating a routine that can optionally be incorporated in the data rate optimization algorithms of FIGS. 3 or 4 to consider the transport protocol of the input data transmission.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawings, wherein like numerals designate like components, FIG. 1 is a diagram of a typical pathway **100** for an end-to-end data transmission from a sending device **101** to a wireless mobile receiving device **105** in accordance with the preferred embodiment of the present invention. The sending device **101** can be a computer, server, or other storage device. Accordingly, as used herein,

sending device **101** refers to each of these devices and their equivalents. The wireless mobile receiving device **105** can be a telephone, a cable telephony interface device, a cellular or personal communications system (PCS) radiotelephone, a cordless radiotelephone, a radio, a personal digital assistant (PDA), a pager, a palm-top computer, a personal computer, or other wireless device for wireless communications. Accordingly, as used herein, wireless mobile receiving device **105** refers to each of these devices and their equivalents.

As shown, the sending device **101** is connected via a computer equipment infrastructure **102**, a wireless infrastructure **103**, and a RF forward link **104** to the wireless mobile receiving device **105**. The wireless infrastructure **103**, RF forward link **104**, and wireless mobile receiving device **105** being a subset of a more comprehensive spread-spectrum communications system **106**. In the preferred embodiment of the present invention, the spread-spectrum communications system **106** is a 3G wireless cellular network utilizing a CDMA air interface communication protocol such as cdma2000 or WCDMA. However, in alternate embodiments the spread-spectrum communications system **106** may utilize other wireless technology (e.g., cellular or satellite communications technology) and other system protocols (e.g., IS-95 or cdmaOne, IS-136 or DAMPS, GSM, and PDC).

As shown, the data transmission originates from the sending device **101** having access to the wireless infrastructure **103** via the computer equipment infrastructure **102**. The path of the data transmission through the computer equipment infrastructure **102**, wireless infrastructure **103**, and RF forward link **104** can be characterized as a communication channel **107**. In reality, this communication channel **107** is created by routing the data transmission through numerous devices and over a variety of types of transmission lines. Each device and transmission line participating in the data transmission has a link width **108** or throughput capacity. In order to simplify the description of the preferred embodiment of the present invention, FIG. 1 depicts the link width **108** or throughput capacity for the communication channel **107** as either a maximum link width or a minimum link width. In actuality, the link width **108** of the communication channel **107** is based on the individual throughput capacity of each device and transmission line participating in the data transmission.

As shown, the link width **108** of the data transmission is initially based on the throughput capacity of the sending device **101** and is depicted at the maximum link width. The initial data rate of bearer data **109** is equivalent to the link width **108** or throughput capacity of the sending device **101**. When the data transmission encounters a device or transmission line with a lower throughput capacity, a bottleneck **110** is created and the data rate of bearer data **109** is limited according to the throughput capacity of the slower device or transmission line. The device or transmission line with the lowest throughput capacity defines the bottleneck link speed for the communication channel **107**. It is possible for the bottleneck link speed for the end-to-end data transmission from the sending device **101** to the wireless mobile receiving device **105** to be established by a device or transmission line within the computer equipment infrastructure **102**. This situation is depicted by the bottleneck **110** of FIG. 1 in the computer equipment infrastructure **102**. Under such circumstances, the data rate of bearer data **109** is limited to the data rate at the bottleneck **110** in the computer equipment infrastructure **102** for the remainder of data transmission via the communication channel **107**. The data rate of bearer data **109** remains at the bottleneck link speed even if the link width **108** of subsequent devices and transmission lines participating in the data transmission provide a higher throughput capacity. Therefore, limitation of the link width **108** or throughput capacity of subsequent devices and/or transmission lines to at or near the bottleneck link speed has no detrimental impact on the overall data transmission. Accordingly, where such a limitation of the link width **108** or throughput capacity provides economy and/or efficiency to the overall communications system, such as in the spread-spectrum communications system **106,** it would be beneficial and advantageous to do so.

In the spread-spectrum communications system **106**, limiting the link width **108** of individual data transmissions is desirable because it permits the comprehensive communications system to establish more communication channels **107**, thereby maximizing system capacity. As shown in FIG. 1, the wireless infrastructure **103** of the preferred embodiment includes an SDU **111** that is capable of adjusting the link width **108** in the subsequent communication channel **107** for the subject data transmission to at or near the data rate of bearer data **109** transmitted at the bottleneck link speed. Therefore, while the data rate of the data transmission to the wireless mobile receiving

device **105** via the RF forward link **104** is not effected by the adjusted link width **108**, the comprehensive spread-spectrum communications system **106** is able to reduce RF waste and maximize system capacity.

Referring to FIG. 2, the end-to-end data transmission of FIG. 1 is depicted in a block diagram that identifies pertinent elements of the spread-spectrum communications system **106** in accordance with the preferred embodiment of the present invention. As shown, the SDU **111** receives a data transmission from the sending device **101** via the computer equipment infrastructure **102**. The SDU **111** performs certain processing functions related to routing and transmitting the data transmission through the wireless infrastructure **112** of the spread-spectrum communications system **106** to the wireless mobile receiving device **105**. Ultimately, the appropriate cell **113** of the spread-spectrum communications system **106** is selected and the data transmission is routed to the base transceiver system (BTS) **114**. The BTS **114** communicates the data transmission to the wireless mobile receiving device **105** via the RF forward link **104**.

As shown, the SDU **111** includes an input data buffer **115**, output data queue **116**, processor **117**, and data rate assignment circuitry **118**. The input data buffer **115** receives the incoming stream of packetized data for the data transmission. As described above, the SDU **111** performs certain processing functions related to routing and transmitting the packetized data through the wireless infrastructure **112** of the spread-spectrum communications system **106**. Such processing functions are performed by the processor **117** and include maintaining data received via the input data buffer **115** in the output data queue **116** until it is transmitted to the remainder of the wireless infrastructure **112**. Such processing functions also include assignment and control of the data rate for such transmissions. The processor **117** determines the appropriate data rate for such transmissions and provides the selected data rate to the data rate assignment circuitry **118**. The data rate assignment circuitry **118** ensures that subsequent data transmissions to the remainder of the wireless infrastructure **112** are transmitted at the selected data rate. It should be understood that the SDU **111** has a plurality of input data buffers **115** and output data queues **116** and is capable of processing multiple data transmissions simultaneously, an input data buffer **115** and output data queue **116** being assigned to each data transmission being processed.

Therefore, such data rate processing within the SDU **111** assumes there are N active data transmissions or calls. The maximum link width or data rate for each data transmission or call is referred to as $c^1 \ldots c^N$. The current link width or data rate for each data transmission or call is referred to a $r^1 \ldots r^N$, where $r^i$ must be less than or equal to $c^i$. The queue size for each data transmission or call is referred to as $q^1 \ldots q^N$. The input data rate for each data transmission or call is referred to as $s^1 \ldots s^N$. The data rate selected for data transmission by the SDU **111** is referred to as the optimized data rate ($r^{opt}$) because it is intended to be at or near the bottleneck link speed of the data transmission that is being processed.

The data rate optimization algorithms to be described in subsequent paragraphs refer to a term ($q_{avg}$) as the "average size of the queue." As disclosed herein, the "average size of the queue" is an accumulated value that is updated during each cycle of the algorithm using a special averaging technique. Rather than a traditional average, the "average size of the queue" is obtained by adding the current size of the queue ($q_n$) to the current average size of the queue ($q_{avg}$) using a weighting factor ($a$) according to the equation $q_{avg} = a * q_{avg} + (1\text{-}a) * q_n$. The weighting factor ($a$) can range between zero and one. Preferably, the weighting factor ($a$) is between 0.5 and 0.9 to produce a damping effect with respect to the degree of influence the current size of the queue ($q_n$) has on the average size of the queue ($q_{avg}$). For example, if the weighting factor ($a$) is 0.7, the updated "average size of the queue" is $0.7q_{avg} + 0.3q_n$. Note the inverse relationship between the coefficient ($a$) of the current average size of the queue ($q_{avg}$) and the coefficient ($1\text{-}a$) of the current size of the queue ($q_n$). When the weighting factor ($a$) is between 0.5 and 0.9, this inverse relationship causes the updated average to be less influenced by the current size of the queue ($q_n$) and more influenced by the current average size of the queue ($q_{avg}$).

In the preferred embodiment, $r^{opt}$ is determined by applying a data rate optimization algorithm as represented by the following pseudo code:

```
q_avg = a * q_avg + (1-a) * q_n;          /* a ∈ (0,1), average size of queue */
If (q_avg < Q^low)
        r_int = r^opt_n - b;              /* b could be a fraction of c */
else if (Q^low =< q_avg < Q^high)
```

$r_{int} = r^{opt}_n$; /* desirable queue region */

else /* $q_{avg} >= Q^{high}$ */

$r_{int} = d * r^{opt}_n$; /* $d > 1$ */

$r^{opt}_{n+1} = (1-f) * r^{opt}_n + f * r_{int}$; /* $f \in (0,1)$ */

Where:

$q_n$ is the current size of the queue for the data transmission;

$a$ is a value between 0 and 1, typically between 0.5 and 0.9;

$q_{avg}$ is the average size of the queue which is accumulated from $q_n$ and dampened according to $a$;

$Q^{low}$ is the low threshold for the average size of the queue;

$r^{opt}_n$ is the current optimized data rate for the data transmission via the wireless infrastructure;

$b$ is a value less than the current optimized data rate;

$r_{int}$ is an internal variable used in calculating the optimized data rate;

$Q^{high}$ is the high threshold for the average size of the queue;

$d$ is a value greater than 1, but less than $c^N/r^{opt}_n$;

$f$ is a value between 0 and 1; and,

$r^{opt}_{n+1}$ is the new optimized data rate that is accumulated from $r_{int}$ and dampened according to $f$.

The data rate optimization algorithm of the preferred embodiment operates under the premise that an optimized data rate in the spread-spectrum communications system **106** is achieved when the average size of the queue maintained in the SDU for a given data communication is maintained between $Q^{low}$ and $Q^{high}$. If the average size of the queue is below $Q^{low}$, the current data rate is above the bottleneck link speed for the data transmission. Therefore, the data rate in the spread-spectrum communications system **106** can be decreased to increase system capacity without impacting the performance perceived by the user at the wireless mobile receiving device **105**. If the average size of the queue is above $Q^{high}$, the current data rate is below the bottleneck link speed for the data transmission. Therefore, the data rate in the spread-spectrum communications system **106** can be increased to reduce transmission delays to the

wireless mobile device. When the average size of the queue is between $Q^{low}$ and $Q^{high}$, the current data rate is sufficiently near the bottleneck link speed of the data transmission. Therefore, the data rate in the spread-spectrum communications system **106** will remain relatively constant.

Referring briefly to FIGS. 3 and 4, the data rate optimization algorithms **200** and **300** of the present invention presume that an RF forward link **104** has been established between the wireless infrastructure **103** and a wireless mobile receiving device **105** and that data transmissions have begun at a predetermined initial data rate. It is common for the predetermined initial data rate to be the minimum data rate that still maintains a sufficient QoS to the wireless mobile receiving device **105**. However, other parameters (e.g., previous data rates, current data rates, average data rates, etc.) and any combination of parameters may be considered when establishing the initial data rate without impacting the algorithms **200** and **300** of the present invention.

Referring to FIG. 3, a flow chart illustrating the data rate optimization algorithm **200** of the preferred embodiment of the present invention is shown. The data rate optimization algorithm **200** begins at step **201** by resetting its internal counter (n) to zero. As the algorithm **200** proceeds, $r^{opt}$ is updated and allocated every T msec. The algorithm **200** performs according to the previously described pseudo code and as described in further detail below for each $n^{th}$ update to $r^{opt}$. At step **202,** the processor obtains the current size of the queue ($q_n$) for the data transmission and computes an average size of the queue ($q_{avg}$) according to the equation $q_{avg} = a * q_{avg} + (1\text{-}a) * q_n$. At step **203,** the processor compares $q_{avg}$ to $Q^{low}$. If $q_{avg}$ is less than $Q^{low}$, the processor proceeds to step **204**, otherwise it proceeds to step **205**. When $q_{avg}$ is less than $Q^{low}$, step **204** will call for a decrease in $r^{opt}{}_{n+1}$. At step **204,** an internal variable ($r_{int}$) will be computed according to the equation $r_{int} = r^{opt}{}_n - b$. The processor will next proceed to step **206** and compute $r^{opt}{}_{n+1}$ according to the equation $r^{opt}{}_{n+1} = (1\text{-}f) * r^{opt}{}_n + f * r_{int}$. The processor will next proceed to step **207** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **208** and increment its internal counter (n) by 1. The processor will continue to process the algorithm by recycling to step **202** as long as the data transmission is active.

The processor reaches step **205** if $q_{avg}$ is not less than $Q^{low}$. At step **205**, the processor compares $q_{avg}$ to $Q^{high}$. If $q_{avg}$ is greater than or equal to $Q^{high}$, the processor proceeds to step **209**, otherwise it proceeds to step **210**. When $q_{avg}$ is greater than or equal to $Q^{high}$, step **209** will call for an increase in $r^{opt}{}_{n+1}$. At step **209**, an internal variable ($r_{int}$) will be computed according to the equation $r_{int} = r^{opt}{}_n * d$. The processor will next proceed to step **206** and compute $r^{opt}{}_{n+1}$ according to the equation $r^{opt}{}_{n+1} = (1\text{-}f) * r^{opt}{}_n + f * r_{int}$. The processor will next proceed to step **207** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **208** and increment its internal counter (n) by 1. The processor will continue to process the algorithm by recycling to step **202** as long as the data transmission is active.

The processor reaches step **210** if $q_{avg}$ is not less than $Q^{low}$ and also not greater than or equal to $Q^{high}$. At step **210**, the processor sets $r^{opt}{}_{n+1}$ equal to $r^{opt}{}_n$. The processor will next proceed to step **207** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **208** and increment its internal counter (n) by 1. The processor will continue to process the algorithm by recycling to step **202** as long as the data transmission is active.

In an alternate embodiment, $r^{opt}$ is determined by applying a modified data rate optimization algorithm that introduces consideration of the input data rate of the data transmission to the SDU as represented by the following pseudo code:

```
q_avg = a * q_avg + (1-a) * q_n;
If (q_avg < Q^low)
        r_int = s_n - b;
else if (Q^low =< q_avg < Q^high)
        r_int = s_n;                    /* maintain queue size */
else                                    /* q_avg >= Q^high */
        r_int = d * s_n;                /* d > 1 */
r^opt_n+1 = (1-f) *r^opt_n + f * r_int; /* f ∈ (0,1) */
```

Where:

$q_n$ is the current size of the queue for the data transmission;

$a$ is a value between 0 and 1, typically between 0.5 and 0.9;

$q_{avg}$ is the average size of the queue which is accumulated from $q_n$ and dampened according to $a$;

$Q^{low}$ is the low threshold for the average size of the queue;

$s_n$ is the current input data rate for the data transmission from the computer equipment infrastructure;

$b$ is a value less than the current input data rate;

$r_{int}$ is an internal variable used in calculating the optimized data rate;

$Q^{high}$ is the high threshold for the average size of the queue;

$d$ is a value greater than 1, but less than $c^N/s_n$;

$f$ is a value between 0 and 1;

$r^{opt}{}_n$ is the current optimized data rate for the data transmission via the wireless infrastructure; and,

$r^{opt}{}_{n+1}$ is the new optimized data rate that is accumulated from $r_{int}$ and dampened according to $f$.

Referring to FIG. 4, a flow chart illustrating an alternate embodiment of the data rate optimization algorithm **300** of the present invention that considers the data rate of the input data transmission is shown. The data rate optimization algorithm **300** begins at step **301** by resetting its internal counter (n) to zero. As the algorithm **300** proceeds, $r^{opt}$ is updated and allocated every T msec. The algorithm **300** performs according to the pseudo code described above and as described in further detail below for each $n^{th}$ update to $r^{opt}$. At step **302**, the processor obtains the current size of the queue ($q_n$) and the current input data rate ($s_n$) for the data transmission and computes an average size of the queue ($q_{avg}$) according to the equation $q_{avg} = a * q_{avg} + (1\text{-}a) * q_n$. At step **303**, the processor compares $q_{avg}$ to $Q^{low}$. If $q_{avg}$ is less than $Q^{low}$, the processor proceeds to step **304**, otherwise it proceeds to step **305**. When $q_{avg}$ is less than $Q^{low}$, step **304** will call for a decrease in $r^{opt}{}_{n+1}$. At step **304**, an internal variable ($r_{int}$) will be computed according to the equation $r_{int} = s_n - b$. The processor will next proceed to step **306** and compute $r^{opt}{}_{n+1}$ according to the equation $r^{opt}{}_{n+1} = (1\text{-}f) * r^{opt}{}_n + f * r_{int}$. The processor will next proceed to step **307** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **308** and increment its internal counter (n)

by 1. The processor will continue to process the algorithm by recycling to step **302** as long as the data transmission is active.

The processor reaches step **305** if $q_{avg}$ is not less than $Q^{low}$. At step **305**, the processor compares $q_{avg}$ to $Q^{high}$. If $q_{avg}$ is greater than or equal to $Q^{high}$, the processor proceeds to step **309**, otherwise it proceeds to step **310**. When $q_{avg}$ is greater than or equal to $Q^{high}$, step **309** will call for an increase in $r^{opt}_{n+1}$. At step **309**, an internal variable ($r_{int}$) will be computed according to the equation $r_{int} = s_n * d$. The processor will next proceed to step **306** and compute $r^{opt}_{n+1}$ according to the equation $r^{opt}_{n+1} = (1\text{-}f) * r^{opt}_n + f * r_{int}$. The processor will next proceed to step **307** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **308** and increment its internal counter (n) by 1. The processor will continue to process the algorithm by recycling to step **302** as long as the data transmission is active.

The processor reaches step **310** if $q_{avg}$ is not less than $Q^{low}$ and also not greater than or equal to $Q^{high}$. At step **310**, the processor sets $r^{opt}_{n+1}$ equal to $r^{opt}_n$. The processor will next proceed to step **307** and communicate the new data rate to the data rate assignment circuitry in the SDU. The processor will next proceed to step **308** and increment its internal counter (n) by 1. The processor will continue to process the algorithm by recycling to step **302** as long as the data transmission is active.

Referring to FIG. 5, a flow chart illustrating a routine **400** that can optionally be incorporated in the data rate optimization algorithms of FIG. 3 or FIG. 4 is shown. The optional routine **400** introduces the consideration of the transport protocol of the input data transmission to the SDU in either algorithm. As step **401** indicates, the optional routine 400 begins after FIG. 3, step 201 or FIG. 4, step 301 depending on which embodiment of the data rate optimization algorithm is implemented. At step **402**, the processor checks if the transport protocol of the input data is TCP. If the transport protocol is TCP, the processor proceeds to step **403**, otherwise it proceeds to step **404**. At step **403**, the processor sets the values for the constants in the data rate optimization algorithm (i.e., a, b, d, f, $Q^{low}$, and $Q^{high}$) to pre-selected values stored in parameter set A. The parameter values stored in parameter set A are uniquely tailored to data transmissions from a computer equipment infrastructure using TCP. As step **405** indicates, the processor will next continue the data rate optimization algorithm at FIG. 3, step 202 or

FIG. 4, step 302 depending on which embodiment of the data rate optimization algorithm is implemented.

The processor reaches step **404** if the transport protocol is not TCP. When the transport protocol is not TCP, it is presumed to be UDP. Therefore, at step **404**, the processor sets the values for the constants in the data rate optimization algorithm (i.e., a, b, d, f, $Q^{low}$, and $Q^{high}$) to pre-selected values stored in parameter set B. The parameter values stored in parameter set B are uniquely tailored to data transmissions from an computer equipment infrastructure using UDP. As step **405** indicates, the processor will next continue the data rate optimization algorithm at FIG. 3, step 202 or FIG. 4, step 302 depending on which embodiment of the data rate optimization algorithm is implemented.

Summarizing the detailed description provided above, the several embodiments provide an apparatus and method that optimizes the data rate for data transmissions in an RF forward link **104** of spread-spectrum communications systems **106**. The apparatus and method addresses and fulfills the previously mentioned need to maximize usage of the transmission bandwidth within the spread-spectrum communications system **106**, while also maintaining a sufficient QoS to the wireless mobile receiving unit **105**. The data rate is optimized at the SDU **111** of the wireless infrastructure **103** of the spread-spectrum communications system **106**. The optimization is accomplished by estimating or measuring the bottleneck link speed of the data transmission and adjusting the data rate for the RF forward link **104** according to the several embodiments of the present invention.

As for the apparatus of the present invention, the spread-spectrum communications system **106** comprises a wireless infrastructure **103**, at least one wireless mobile receiving device **105**, and an RF forward link **104** between the wireless infrastructure **103** and the wireless mobile receiving device **105**. The wireless infrastructure **103** further comprises at least one SDU **111**, the SDU **111** including an input data buffer **115**, an output data queue **116**, a processor **117**, and rate assignment circuitry **118**.

It should be understood that the implementation of other variations and modifications of the invention in its various aspects will be apparent to those of ordinary skill in the art, and that the invention is not limited by the specific embodiments

described. For example, one of ordinary skill in the art will recognize that the data rate optimization algorithms in either embodiment described above could be implemented for input data transmissions from a computer equipment infrastructure using transmission protocols other than the TCP or UDP protocols described. Furthermore, one of ordinary skill in the art will also recognize that the data rate optimization algorithms in either embodiment described above could be implemented for input data transmissions from other sources than the computer equipment infrastructure described. It is the intent of the inventors that such modifications can be made to the present invention without varying from the spirit and scope of the invention, and it is intended that all such modifications come within the scope of the following claims and their equivalents.